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Major Weeds in Rainfed Rice-Onion Cropping Systems in the Asian Site in the Philippines

By
A.M. Baltazar, University of the Philippines at Los Banos, College
E.C. Martin, Philippine Rice Research Institute
M.C. Casimero, Philippine Rice Research Institute
F.V. Bariuan, University of the Philippines at Los Banos, College
S.R. Obien, Philippine Rice Research Institute
and
S.K. De Datta, Virginia Tech

IPM CRSP
Office of International Research and Development
1060 Litton Reaves Hall
Virginia Tech
Blacksburg, VA 24061-0334

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Contact Address for the Management Entity

IPM CRSP
Office of International Research and Development
1060 Litton Reaves Hall
Virginia Tech
Blacksburg, VA 24061-0334

Telephone (540) 231-3513
FAX (540) 231-3519

E-mail: BRHANE@vt.edu

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MAJOR WEEDS IN RAINFED RICE-ONION CROPPING SYSTEMS IN THE ASIAN SITE IN THE PHILIPPINES[1]

A.M. Baltazar[2], E.C. Martin[3], M.C. Casimero[3], F.V. Bariuan[2], S.R. Obien[3] and S.K. De Datta[4]

Summary

The major weeds infesting rainfed rice-onion systems were identified in 13 farms in three villages in San Jose, Nueva Ecija, the IPM CRSP Asian site. The kind and density of weed species were determined using the quadrat sampling method from 1994 to 1996 wet and dry seasons. About 20 weed species each were observed in the rice and onion crops with three species in each crop emerging as most dominant. These were ***Ludwigia octovalvis, Cyperus rotundus,*** and ***Echinochloa*** spp. in rice and ***Cyperus rotundus***, ***Cleome viscosa*** and ***Trianthema portulacastrum*** in onion. Two of the villages had more species and more kinds of weeds than the third village. A carry over of dominant weeds across crops occurred distinctly in all the three villages. Certain upland species normally occurring only during the onion crop are increasing in populations in lowland rice, apparently caused by insufficient flooding during the rice rotation and enhanced by the alternate wet-dry annual rotation pattern. Over time, this could result in dominant species shifts in rainfed rice-vegetable cropping systems not only in the Asian site but also in other rainfed areas in the country with similar cropping patterns and weed populations.

Introduction

One-half of the 3.2M ha rice-growing areas in the Philippines are rainfed areas with rice-based multiple cropping systems. Among these is the IPM CRSP Asian site, which is located in the town of San Jose in the province of Nueva Ecija, some 160 kilometers northeast of Manila. The climate in the site is characterized by 4 months of wet season with about 350 mm rainfall per month (June to September) and 6 months of dry season with about 30 mm rainfall per month (November to April) (Anonymous, 1990). May and October are transition periods between the wet and dry seasons with a 150 mm average rainfall.

Because of inadequate irrigation facilities, farmers in these areas depend partially or totally on rainfall. Thus, they grow lowland rice in rotation with upland crops (vegetables) in a pattern that coincides with the annual rainfall distribution. One crop of lowland rice is grown in the wet season (June to October) and one or

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[2]Associate Professor and Research Associate, University of the Philippines at Los Baños, College, Laguna 4031, Philippines.

[3]Research Specialists and Director, Philippine Rice Research Institute, Muñoz, Nueva Ecija, Philippines.

[4] Director, Office of International Research and Development, and Associate Dean, College of Agriculture and Life Sciences, Virginia Tech., Blacksburg, VA, 24061-0334, USA.

two crops of vegetables in the dry season (November to May) with fallow periods in between seasons (Figure 1). In most of the farms, onion is the main or sole crop and string beans, eggplant, pepper and similar vegetables are secondary crops during the dry season.

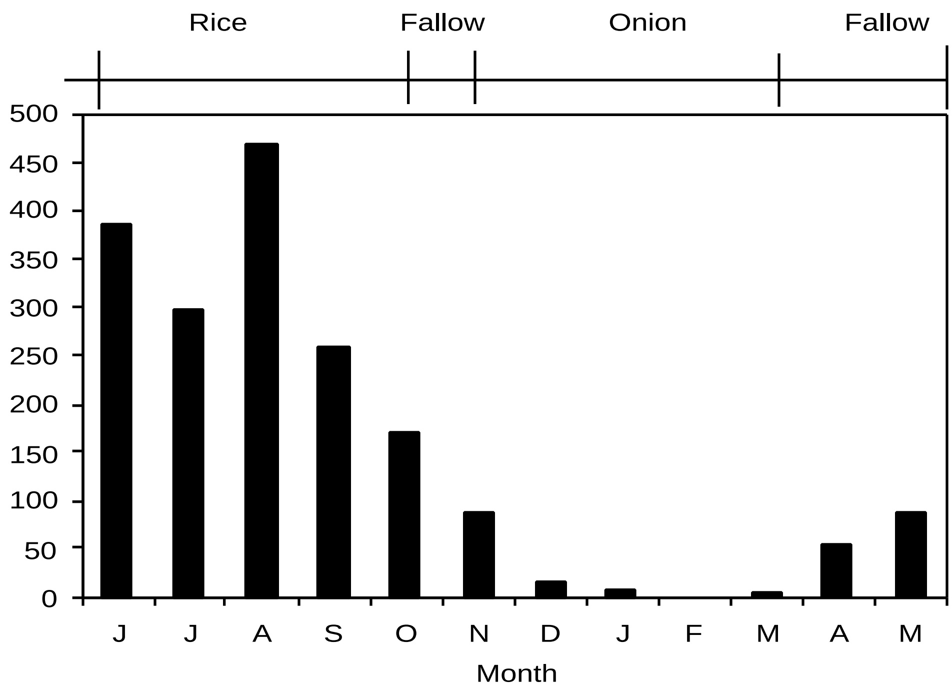


Figure 1. Cropping seasons and annual rainfall distribution pattern in Sa Jose, Nueva Ecija, Philippines.

In determining integrated management strategies against weeds infesting multi-crop systems, the first step is to identify the major problem weeds that compete with and reduce yields of the component crops. Past surveys conducted to identify the weed flora in single crop systems showed that the dominant weeds are defined by the water management associated with the crop: aquatic or semi-aquatic weeds in lowland rice and terrestrial weeds in upland crops. For the past 20 years or so in Nueva Ecija, these lowland rice weeds include aquatic weeds such as ***Echinochloa glabrescens, Monochoria vaginalis, Paspalum distichum, Ludwigia octovalvis, Fimbristylis miliacea, Ischaemum rugosum, Cyperus iria*** and ***Scirpus supinos*** (Pablico and Moody, 1985; 1986). In vegetables, the dominant weeds are terrestrial weeds such as ***Eleusine indica, Portulaca oleracea, Cynodon dactylon, Cyperus rotundus, Echinochloa colona, Ipomoea triloba, Trianthema portulacastrum, Digitaria sanguinalis, Amaranthus spinosus, Cleome rutidosperma,*** and ***Commelina benghalensis*** (Paller et al, 1979; Paller and Magsino, 1984; Moody, 1992).

In general, previous surveys have focused on weed flora based on a single crop and did not determine weed growth patterns in multi-crop systems. With two or even three crops a year, weed dominance in multi-crop systems is the result of the cropping pattern and its associated management or cultural practices, rather than a simple case of crop-weed competition and succession (Bantilan et al, 1974; Harwood and Bantilan, 1974). In rainfed areas with rice-based cropping systems, fields are usually dry to saturated during the vegetable crop and are submerged in about 5 cm water during the rice crop. In the rotation pattern practiced in San Jose, semi-aquatic or aquatic weeds grow with lowland rice during the wet season and terrestrial weeds grow with vegetables during the dry season. Consequently, aquatic or semi-aquatic weeds grow alternately with terrestrial weeds on the same piece of land in an annual cycle. This means that different weeds, depending on soil moisture levels, occupy the same physical location at various times of the year. To our knowledge, no field surveys have yet been conducted to determine the weed flora in rainfed rice-onion systems or to compare the dominant weeds in multi-crop systems and mono-crop systems.

This study was conducted to determine the kind and density of weeds growing in rice-onion crops rotated in an annual cycle in rainfed areas in San Jose, Nueva Ecija. The implication of the weed flora on subsequent management practices in multi-crop systems as compared with mono-crop systems is discussed.

Materials and Methods

Weed surveys were conducted in 13 farmers' fields in three villages in the Asian site, in the town of San Jose, province of Nueva Ecija, Philippines. The villages were Abar 1st (Location 1), Santo Tomas (Location 2), and Palestina (Location 3). The sampling sites consisted of four fields each for Abar 1st and Santo Tomas and five fields for Palestina. For Location 1 (Abar 1st) and Location 2 (Santo Tomas), sampling was done from September to October 1994 (late wet season, rice), then from December 1994 to March 1995 (dry season, onion), and from June to October 1995 (wet season, rice). For Location 3 (Palestina), sampling was done from June to October 1996 (wet season, rice) and from December 1996 to March 1997 (dry season, onion).

The kinds of weed species and their densities were determined by the quadrat sampling method. Weeds from a 1m x 1m quadrat were hand-pulled from the soil, with the roots intact. Each sample was identified and counted by species. The counted samples were placed in paper bags, oven-dried at 70°C for 72 hours, and dry weights were recorded.

In each field, sampling was done three times at various periods during the season: early season (30-45 days after planting), mid-season (60-70 days after planting), and late season (7 days before harvest). At each sampling time in each field, three quadrats were laid out at random. Thus, in each crop (rice and onion), a total of 36 quadrats each were sampled for Abar 1st and Santo Tomas (Locations 1 and 2). In Palestina (Location 3), a total of 45 quadrats were sampled in each crop (rice and onion).

Weed dominance was expressed as the summed dominance ratio (SDR) of relative density (RD) and relative dry weight (RDW) calculated as follows:

$$SDR = \frac{RD + RDW}{2};$$

$$\text{where } RD = \frac{\text{no. of individuals in a species}}{\text{total no. of individuals in all species}} \times 100$$

$$\text{and } RDW = \frac{\text{dry weight of individuals in a species}}{\text{total dry weight of individuals in all species}} \times 100$$

Results and Discussion

Data are presented as summed dominance ratios (SDR) averaged across three sampling times (early-, mid-, and late season). Since farmers observed standard weed control practices throughout the season, there were generally low infestation levels as reflected in the weed densities and dry weights (Table 1). Previous surveys also showed generally low levels of infestation in farmers' fields where standard weed control practices in rice are observed (Pablico and Moody, 1985; 1986).

Table 1. Weed density and dry weight in rice and onion at late season in three villages in San Jose, Nueva Ecija (average of 12 quadrats per village).

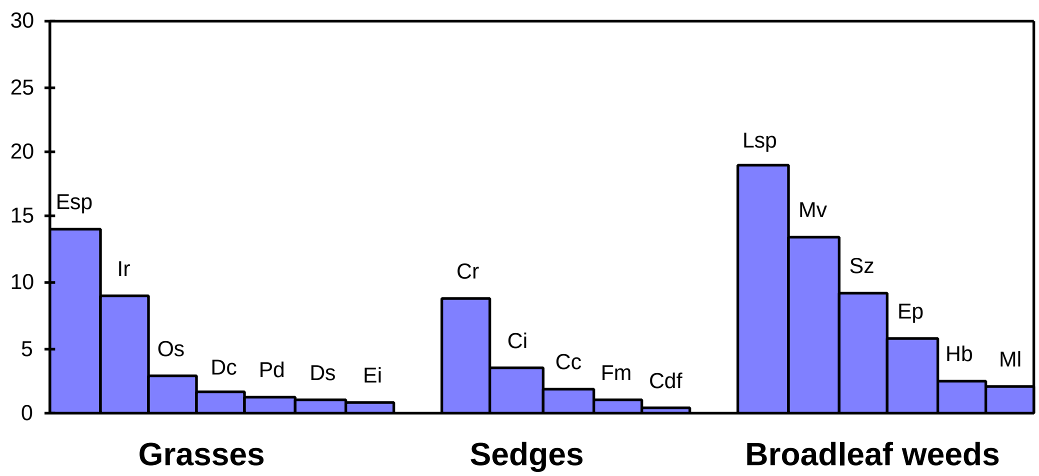
Weed group	Rice			Onion		
	Abar 1st	Sto. Tomas	Palestina	Abar 1st	Sto. Tomas	Palestina
Density (no/m^2)						
Grass	3.0	2.7	3.3	1.9	1.9	12.1
Sedge	2.3	7.3	6.8	2.0	14.1	20.6
Broadleaf	18.1	9.8	7.6	11.8	3.4	14.1
Total	23.4	19.8	17.7	15.7	19.4	46.8
Dry weight (g/m^2)						
Grass	24.3	46.3	4.1	0.6	6.8	14.8
Sedge	5.7	7.3	4.5	0.1	4.9	15.5
Broadleaf	35.1	2.8	5.4	2.2	8.2	14.0
Total	65.1	56.4	14.0	2.9	19.9	44.3

Location 1

Twenty weed species were observed in lowland rice in Abar 1st, in Nueva Ecija province in the Philippines (Figure 2a). More than half (52%) were broadleaf weeds (7 species), 31% were grasses (8 species) and 16% were sedges (5 species). The most dominant species (SDR of 9 or higher), in decreasing order, were ***Ludwigia spp. (L. octovalvis*** and ***L. perennis), Echinochloa spp. (E. glabrescens*** and ***E. crusgalli), Monochoria vaginalis, Sphenochlea zeylanica, Ischaemum rugosum,*** and ***Cyperus rotundus.*** Three other species, ***Oryza sativa,*** (red rice), ***Cyperus iria,*** and ***Eclipta prostrata*** were also prominent although not as dominant as the first six species.

In onion, there were 17 weed species (Figure 2b). About 75% were broadleaf weeds (11 species), 17% were grasses (5 species), and 8% consisted of ***C. rotundus,*** the only sedge present. The most dominant species (SDR of 5 or higher), were ***Cleome viscosa, Phyllanthus amarus, C. rotundus, Cassia tora, Trianthema portulacastrum*** and ***Echinochloa colona.***

2a



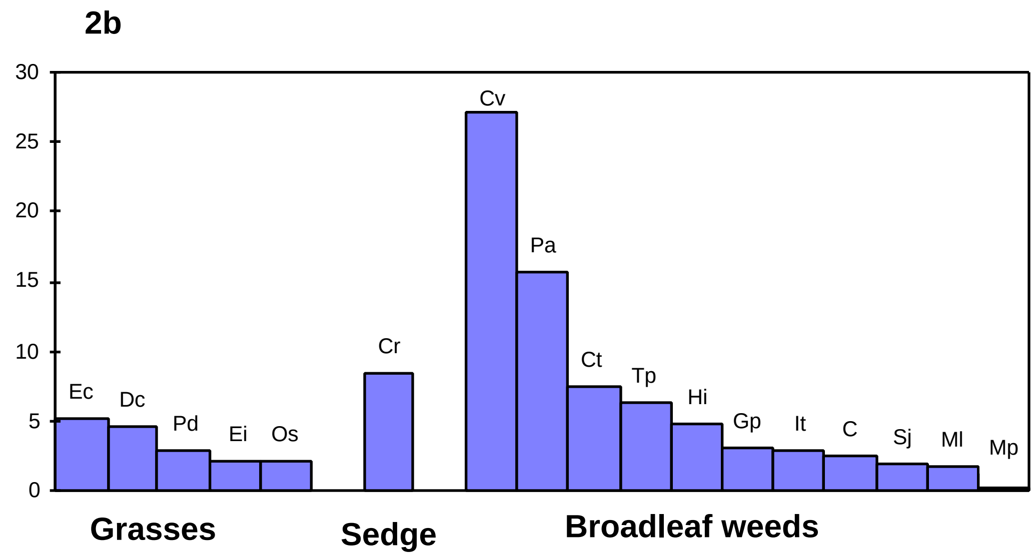


Figure 2. Summed dominance ratio of weeds in rice (2a) and onions (2b) in Abar 1st during the 1994 and 1995 wet and dry seasons.

The predominance of broadleaf weeds in both rice and onion crops reflects the diversity of vegetable crops grown in this village. These crops include pepper, eggplant, string beans, tomato, garlic, and bitter gourd, in addition to onions. The most dominant broadleaf weed in onion, ***Cleome viscosa,*** has not been reported in surveys conducted 10 years ago. In rice, red rice and ***C. rotundus*** were also not reported as major weeds in past surveys.

Location 2

Eighteen weed species were identified in rice in Santo Tomas in Nueva Ecija province in the Philippines (Figure 3a). About 35% were grasses (8 species), 35% were broadleaf weeds (5 species), and 30% were sedges (5 species). Six of these species (SDR of 6 or higher) were most dominant: ***Ludwigia spp., Echinochloa spp., C. rotundus, Cyperus difformis, T. portulacastrum,*** and ***I. rugosum.***

Thirteen weed species were observed in onions (Figure 3b). Almost 60% consisted of ***C. rotundus,*** the only sedge species present. Eight species of broadleaf weeds consisted 22% while four species of grasses consisted 20%. The most dominant, (SDR of 3 or higher), were ***C. rotundus, C. viscosa, O. sativa, T. portulacastrum***, and ***E. colona.***

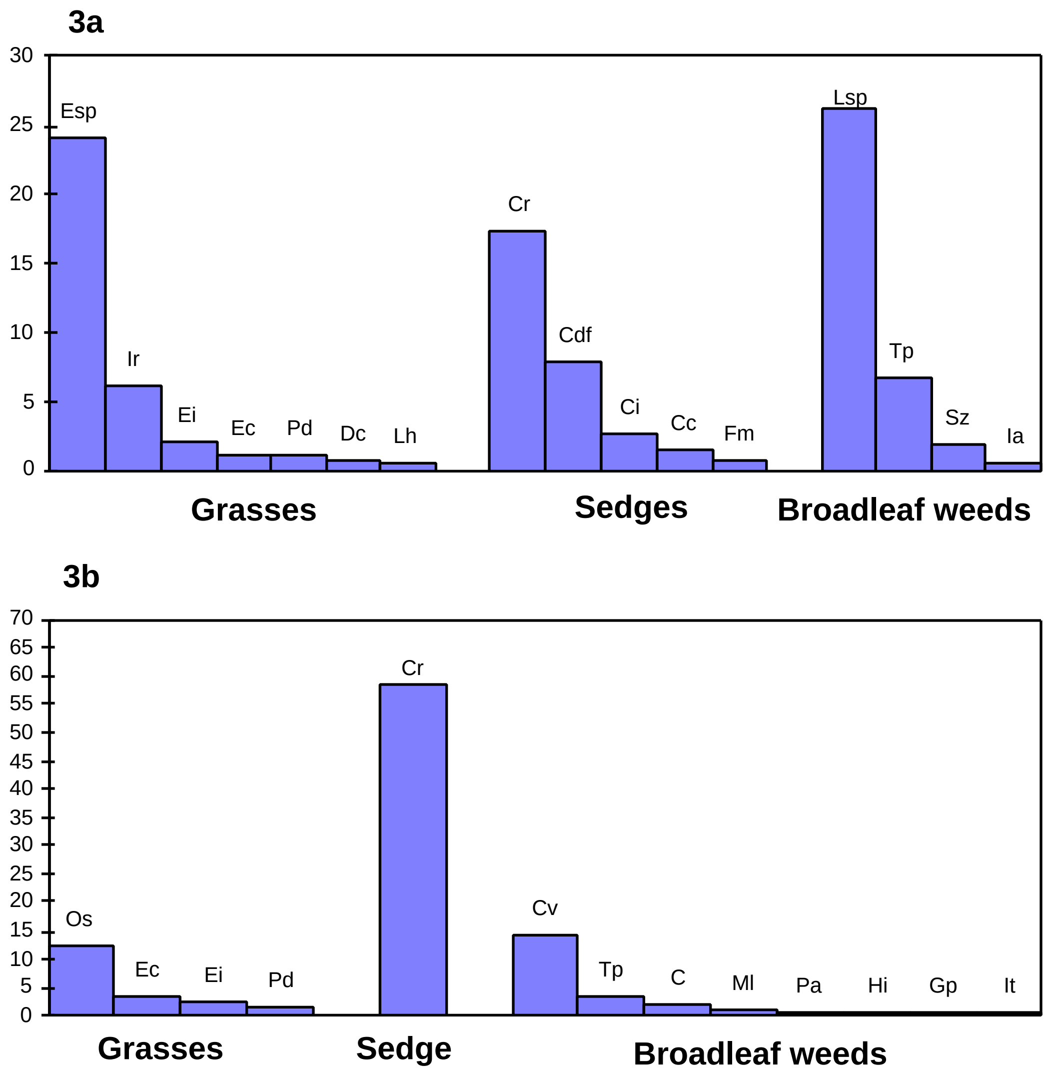


Figure 3. Summed dominance ratio of weeds in rice (3a) and onions (3b) in Santo Tomas during the 1994 and 1995 wet and dry seasons.

In onion, ***C. rotundus*** was clearly the dominant weed throughout the season. At mid-season, it was practically the only species in the whole field, suggesting application of control measures which were effective against the other species but not against this weed. At late season, although broadleaf weeds and grasses increased to about 20-30% each of the total weed population, ***C. rotundus*** still dominated with almost 50% of the weed population.

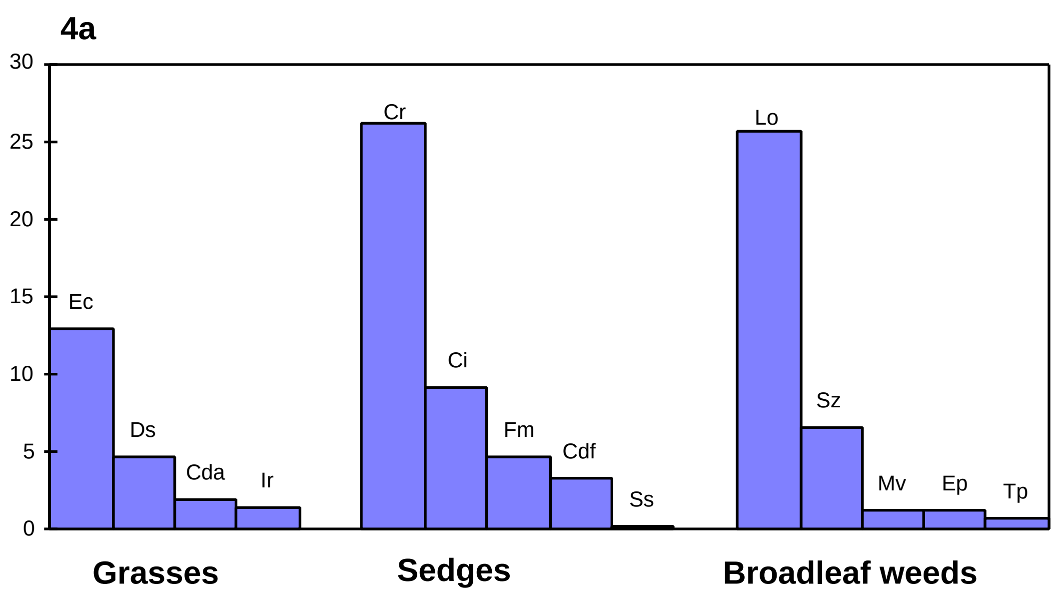
The kind and diversity of broadleaf weed species at late season in onion are similar to those species found in Abar 1st, with ***C. viscosa*** also the dominant broadleaf weed.

In rice, the dominant weeds are similar to those observed in past surveys except for the appearance of upland weeds ***C. rotundus, T. portulacastrum, E. colona,*** and ***E. indica.***

Location 3

Of 14 species growing with rice, 44% were sedges (5 species), 36% were broadleaf weeds (5 species), and 20% were grasses (4 species) in Palestina in Nueva Ecija province in the Philippines (Figure 4a). The most dominant species (SDR of 6 or higher) were ***C. rotundus, Ludwigia spp., E. colona, C. iria,*** and ***S. zeylanica***.

In onion, there were 13 weed species (Figure 4b). The sedges (3 species) consisted 38%; the grasses (4 species) consisted 34% and the broadleaf weeds (6 species) consisted 27%. The most dominant (SDR of 7 or higher) were ***C. rotundus, T. portulacastrum, E. colona, Eleusine indica*** and ***O. sativa*** (volunteer rice).



4b

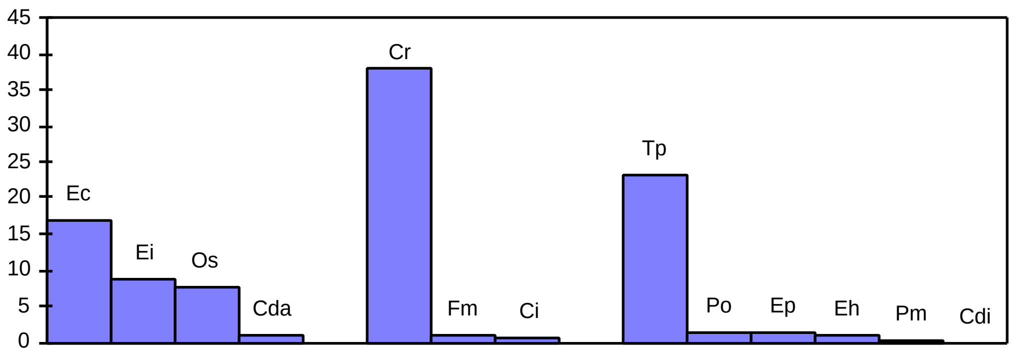


Figure 4. Summed dominance ratio of weeds in rice (4a) and onions (4b) in Palestina during the 1996 and 1997 wet and dry seasons.

Palestina has less diversity of weed species compared to Abar 1st and Santo Tomas, possibly because of the less diversity of vegetable crops. In this village, onion is the sole or main crop and only a few other vegetables are grown. ***C. rotundus*** is clearly the most dominant species in both rice and onion crops.

The absence of ***E. crusgalli,*** usually the dominant weed in fully irrigated rice and the predominance of ***C. rotundus*** and ***E. colona*** and four other upland weeds in rice in this village is particularly interesting. This observation, plus the appearance of ***F. miliacea*** and ***C. iria***, usually weeds in lowland rice, in onion indicates ability of these species to grow in both upland and lowland condition.

The dominant broadleaf weeds in onion in this village are different from those observed in Abar 1st and Santo Tomas. ***C. viscosa***, the dominant broadleaf weed in Abar 1st and Santo Tomas was not observed in this village.

General Discussion

In the three villages, a total of 26 weed species were observed in rice: 9 broadleaf weeds (41%), 11 grasses (29%) and 6 sedges (30%). In onion, 24 weed species were observed: 15 broadleaf weeds (41%), 6 grasses (24%) and 3 sedges (35%).

Although 13 to 20 weed species were growing in each crop, only three, with SDRs of 10 or greater, were most dominant. In Abar 1st, the most dominant species were ***Ludwigia spp, Echinochloa spp. a***nd ***M. vaginalis*** in rice and ***C. viscosa, P.***

amarus, and ***C. rotundus*** in onion. In Santo Tomas, ***Ludwigia spp., Echinochloa spp.,*** and ***C. rotundus*** were dominant in rice and ***C. rotundus, C. viscosa*** and ***O. sativa*** were dominant in onion. In Palestina, the dominant species were ***C. rotundus, Ludwigia spp.,*** and ***E. colona*** in rice and ***C. rotundus, T. portulacastrum*** and ***E. colona*** in onion. Averaged across the three villages, the three most dominant species were ***Ludwigia spp., C. rotundus,*** and ***Echinochloa spp***. in rice and ***C. rotundus, C. viscosa and T. portulacastrum*** in onion. Other dominant species were ***S. zeylanica, I. rugosum, C. iria, M. vaginalis, E. colona*** in rice and ***E. colona, O. sativa, P. amarus*** and ***E. indica*** in onion. Our results agree with those of previous surveys who also reported that of more than 10 species found in a crop field, only three or four species usually pose major problems (Kim and Moody, 1980; Ahmed and Moody, 1980; Moody and Drost, 1983).

The kind and number of weed species varied among the villages. Abar 1st had the most number of species (20 in rice and 17 in onion), followed by Santo Tomas, and Palestina had the least number of species. More broadleaf weeds were observed in Abar 1st and Santo Tomas, than in Palestina, particularly in the onion crop. Most of the weeds found in Abar 1st and Santo Tomas, including its two most dominant weeds, ***C. viscosa*** in onion and ***E. glabrescens*** in rice, were not found in Palestina.

Although the kind of weeds varied among the villages, in each village a carry-over of dominant weeds occurred distinctly across the cropping seasons (Figure 5). Broadleaf weeds, the dominant weeds during the rice season in Abar 1st, were also the dominant weeds during the onion season. In Santo Tomas and Palestina, sedges were the dominant weeds in both rice and onion crops. Carry-over of dominant weeds was particularly evident in Palestina, where ***C. rotundus*** and ***E. colona*** were dominant in both rice and onion crops and only the broadleaf weeds differed in each crop.

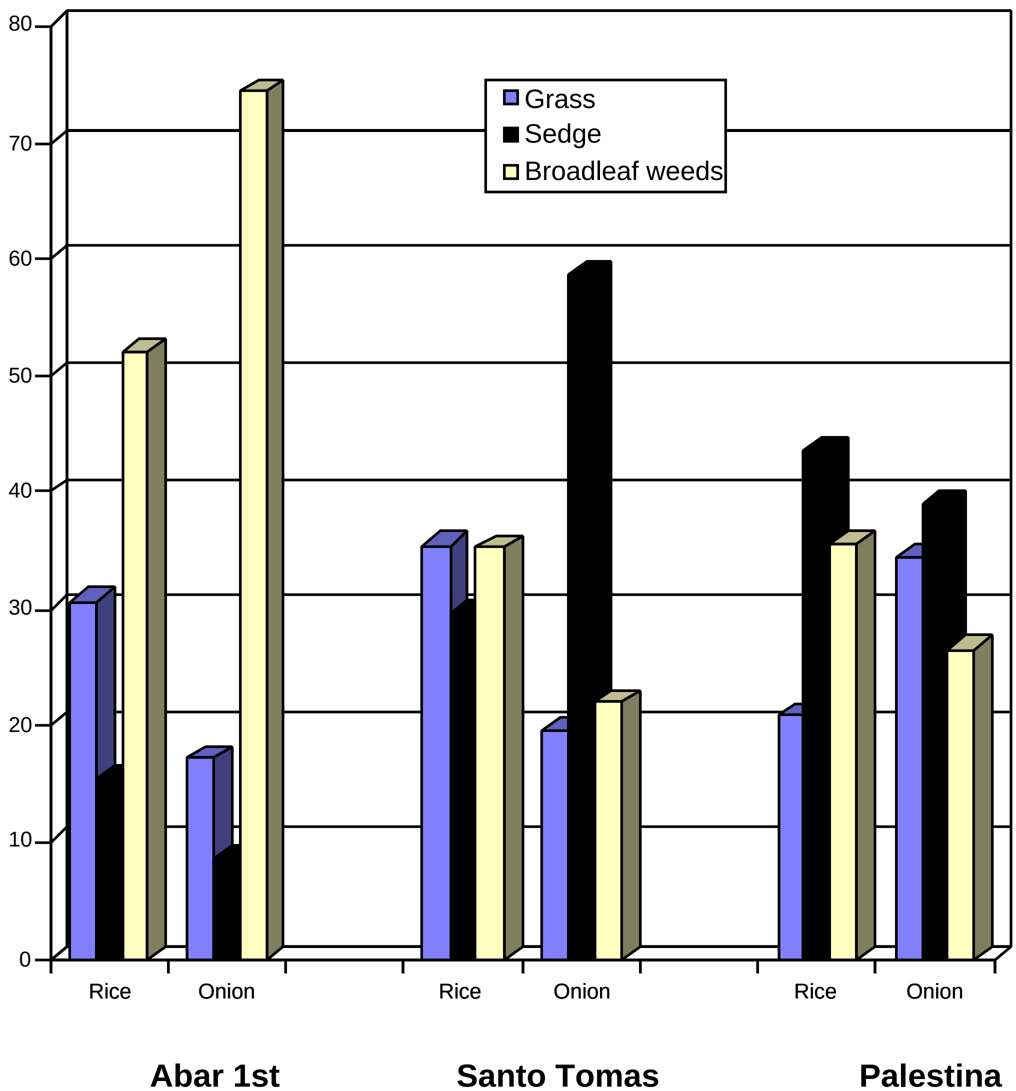


Figure 5. Major weed groups in rice and onion in three villages in San Jose, Nueva Ecija from 1994 to 1997 wet and dry seasons (average of 36 45 quadrats per crop for each village).

These results are in contrast with those of previous studies. No similarity of weeds were observed in rotation systems of upland-lowland rice (Moody, 1979); barley-lowland rice (Choi, 1979), soybean-lowland rice (William and Chiang, 1976), and various dryland crops and lowland rice (Ahmed, 1979). Ahmed and Moody (1980) observed that if the lowland rice is adequately flooded, rotating it with a dryland crop will neither increase nor decrease the weed populations in the rice crop and no carry-over of weeds across crops occur because of well-defined differences in the water management of each crop. In our survey, upland weeds were carried over into lowland rice because of inadequate flooding in the rice crop due to scarce rainfall and inadequate irrigation. Similarly, Estorninos et al (1982) reported the presence of upland weeds in rainfed lowland rice due to inadequate flooding in the rice crop.

Most of the dominant weeds in rice identified in our survey are the same aquatic weeds dominating lowland rice in Nueva Ecija 10 years ago, i.e. ***E. glabrescens, M. vaginalis, L. octovalvis, F. miliacea,*** and ***C. iria*** (Pablico and Moody, 1985; 1986). But six dominant species in onions are now appearing in increasing populations in lowland rice. These are ***C. rotundus, E. colona, E. indica, Digitaria spp., E. prostrata*** and ***T. portulacastrum.*** These weeds were not reported to occur, or were observed only occasionally, in lowland rice in surveys conducted in the 1980s (Pablico and Moody, 1985; 1986).

In integrated weed management, crop rotation is among several agroecological practices used as an indirect method of suppressing weed growth. It has long been recognized as an effective way of preventing weed species build up that is likely to occur in monocrop systems. Because particular weeds grow with particular crops, growing the same crop in the same piece of land repeatedly in monocrop systems inevitably results in weed population build-up. Rotating crops with completely contrasting growth habits or cultural requirements breaks the weed cycle and prevents build-up of any one weed species. For example, even without weeding, rotating lowland rice with upland crops drastically reduced populations of ***Scirpus maritimus***, a weed which accumulates in continuous transplanted irrigated rice (De Datta and Jereza, 1977). Similar crop rotation schemes also reduced populations of other lowland rice weeds (Moody and De Datta, 1977; Moody, 1982; Harwood and Bantilan, 1974). Populations of upland weeds like ***Cyperus rotundus*** were likewise held in check by lowland rice-vegetable rotations in Taiwan (Williams, 1979) and in the Philippines (Moody, 1977b). In practicing the traditional rice-onion rotation scheme to fit the annual rainfall distribution pattern, farmers in rainfed areas in San Jose, Nueva Ecija were thus also effectively keeping weed populations in check and preventing build-up of weeds in either crop.

However, Plucknett et al (1977) had indicated that even with crop rotation, weed build-up problems similar to those that occur in monoculture may result if the same cropping pattern and the same weed control practices are done repeatedly over the years. When the study of weed control in multiple cropping systems was initiated 20 years ago, Plucknett et al (1977) was then aware of the fact that weed control in multi-crop systems is different from that in mono-crop systems. He emphasized the need for constant monitoring of crop and weed management practices and weed growth mechanisms that could lead to weed species build-up or dominant species shifts because of the highly dynamic nature of weeds. Today, 20 years and numerous rice-onion cycles later, our survey in San Jose has confirmed Plucknett's (1977) observations. In the rainfed fields of San Jose, inadequate flooding depths during the lowland crop (rice) growing alternately with an upland crop (onion) in a regular annual cycle over the years is causing an increase in populations of upland weeds in lowland rice. Because of insufficient irrigation, low floodwater levels (Table 2) during periods of scarce rainfall encourages germination and growth of dryland weeds in rice. Holm et al (1977) observed that saturated soil conditions during periods of scarce rainfall or inadequate irrigation after the rice has been transplanted encouraged germination and growth of ***C. rotundus*** in lowland rice. It is also possible that certain weed seeds and propagules subjected to alternately flooded and saturated soils in the course of the rice-onion rotation have acquired adaptation mechanisms to enable their germination and growth in both upland and lowland conditions. Repeated regularly in annual pattern, this rotation system could select for species that could grow in both soil moisture regimes. Over time, this could affect the composition of the weed flora and result in dominant species shifts in rainfed rice-vegetable rotation systems. This is already being exemplified by the increasing dominance of ***Cyperus rotundus*** in both rice and onion crops in Palestina and in Santo Tomas.

Table 2. Rice floodwater level in three villages in San Jose during the 1995 wet season.

Location (Village)	Early season (30-35 DAT)[a]	Mid season (60-70 DAT)[a]	Late season (7 DBH)[a]
Location 1 (Abar 1st)	4.0	7.5	0[b]
Location 2 (Sto. Tomas)	2.5	6.5	0
Location 3 (Palestina)	2.5	0	0

[a]DAT = days after transplanting, DBH = days before harvest.
[b]Saturated soil (no standing water).

Shallower floodwater levels in rainfed rice than in irrigated rice is also shifting dominance in broadleaf and grass species. Among the broadleaf weeds, ***L. octovalvis*** and ***L. perennis*** are now more dominant, based on our survey, than ***M. vaginalis***, the dominant broadleaf species in rice 10 years ago (Pablico and Moody, 1985; 1986). Among the grasses, although ***E. glabrescens*** and ***E. crusgalli*** are still dominant, our survey shows that ***E. colona*** and ***I. rugosum*** are increasing in populations. In Palestina, which has the lowest floodwater levels (Table 2), ***I. rugosum*** and ***E. colona*** are the dominant grasses, and no ***E. crusgalli*** nor ***E. glabrescens*** are observed. Red rice and other weedy forms of rice, which are weeds of dry-seeded or upland rice are also shown in our survey to be increasing in numbers in rainfed lowland rice. Red rice and ***I. rugosum*** are two grass weeds which are increasing in dominance in direct-seeded and rainfed areas because of shallow floodwater levels. These weeds apparently grow better in fields with low soil moisture conditions. In a past survey of weeds in rice in Nueva Ecija, Estorninos et al (1982) observed that ***I. rugosum*** was the major weed in rainfed rice while ***E. crusgalli*** was the major weed in irrigated rice (Table 3).

Table 3. Effect of irrigation regime on major weeds growing in association with transplanted rice in Nueva Ecija, Philippines in 1979. (From Estorninos et al, 1982).

Weed species (Transplanted rice)[a]	
Irrigated	Rainfed
Echinochloa crusgalli spp. hispidula	***Ischaemum rugosum***
Paspalum paspalodes	***Fimbristylis littoralis***
Monochoria vaginalis	***E. crusgalli spp. hispidula***
	Monochoria vaginalis

[a]Listed in order of importance.

Of the upland species now being observed in lowland rice, the most dominant is ***C. rotundus.*** Ten to 20 years ago, ***C. rotundus*** was the dominant weed only in upland rice (De Datta, 1974; Okafor and De Datta, 1974) and other upland crops, particularly vegetables (Paller et al, 1979; Paller and Magsino, 1984; Moody, 1992). It was not observed, or at best, was only a minor weed in lowland rice (Pablico and Moody, 1985; 1986; Carbonell and Moody, 1983). In 1979, Carbonell and Moody (1983) reported that only two farms in Nueva Ecija regarded ***Cyperus rotundus*** as important in rainfed rice (Table 4). Today in our survey, it ranks second most dominant weed in rainfed lowland rice in three villages in San Jose, Nueva Ecija. In a span of more than 10 years in these areas, its densities has increased from occasional (Pablico and Moody, 1985; 1986) to 1-3 plants/m^2 throughout the season in Santo Tomas and Abar 1st and 4-8 plants/m^2 throughout the season in Palestina (Table 5). In Palestina, where it is the most dominant weed in lowland rice, ***C. rotundus*** density peaked at 15 plants/m^2 at early season, apparently before the fields were handweeded. Consisting of an average of 60% of the total sedge population in all three villages (Table 6), it has outranked ***C. iria, C. difformis*** and ***F. miliacea***, the dominant sedges in lowland (irrigated) rice 10 years ago (Pablico and Moody, 1985; 1986).

Table 4. Problem weeds as identified by farmers in irrigated and rainfed areas in Nueva Ecija in 1979. (From Carbonell and Moody, 1983).

Weed Species	No. of farmers	
	Irrigated	Rainfed
Echinochloa crusgalli	61	19
Paspalum distichum	18	4
Monochoria vaginalis	12	14
Sphenoclea zeylanica	2	1
Fimbristylis miliacea	4	27
Ceratophyllum demersum	1	-
Ischaemum rugosum	2	30
Eichhornia crassipes	1	-
Cyperus rotundus	**-**	**2**
Ipomoea aquatica	1	5
Echinochloa colona	-	2
Panicum repens	-	5
Brachiaria mutica	-	2
Leersia hexandra	-	1
Cyperus sp.	-	1

Table 5. ***C. rotundus*** density in rice and onion fields in an annual rotation cycle in three villages in San Jose, Nueva Ecija.

Location (Village)	Crop/Season	SDR[a]	Rank[b]	***C. rotundus*** density (no/m^2) Late season (7 DBH)[c]	Average[d]
Location 1	Rice 1994 WS[c]	8.7	6	1.1	1.0
(Abar 1st)	Onion 1995 DS	8.5	3	2.0	1.1
Location 2	Rice 1994 WS	17.2	3	2.3	2.0
(Sto. Tomas)	Onion 1995 DS	58.6	1	14.1	8.9
Location 3	Rice 1996 WS	26.1	1	4.1	7.9
(Palestina)	Onion 1997 DS	37.9	1	20.6	18.6

[a]SDR = summed dominance ratio
[b]Rank = rank in dominance
[c]DBH = days before harvest, WS = wet season; DS = dry season.
[d]Average of early, mid- and late season samplings.

Table 6. Density of sedges in rice in Palestina during the 1997 early, mid-, and late dry season.

Sedge species	Density (no/m^2)			
	Early season (30-45 DAT)[a]	Mid season (60-70 DAT)[a]	Late season (7DBH)[a]	Average
C. rotundus	15.1	4.5	4.1	7.9
C. iria	1.0	1.9	1.9	1.6
F. miliacea	0.5	2.9	0.5	1.3
C. difformis	1.2	1.3	0.3	0.9
S. supinos	0.2	0.1	0	0.1

[a]DAT = days after transplanting, DBH = days before harvest.

The possible mechanism(s) of adaptation of ***C. rotundus*** to flooded conditions is another subject which is being looked into in other studies in this project. From results of our initial studies, tubers (the major propagules) of ***C. rotundus*** submerged in 3 cm to 5 cm water depths germinated and grew as well as tubers placed in saturated soil (0 cm water depth) (Baltazar et al, 1997). Earlier studies by other researchers have reported that ***C. rotundus*** tubers soaked in water for 200 days did not lose viability (Ueki, 1969). These tubers, upon transfer to favorable growing conditions after soaking, germinated satisfactorily (Ueki, 1969). For this reason, Mercado (1979) had then suggested that conversion of an upland field to a lowland field does not guarantee a reduced ***C. rotundus*** population in the next upland season. Mercado's (1979) observation 20 years ago is now confirmed in our survey.

The increasing dominance of upland weeds, in particular ***Cyperus rotundus***, in the rice rotation means increased infestations in the onion crop because its presence in rice provides a continued supply of propagules into the onion crop. In our survey, a direct relationship between the density of ***C. rotundus*** in both rice and onion crops supports this observation (Table 5). In Abar 1st, where ***C. rotundus*** density in rice is low (1 plant/m^2) its density in onion is also low (1-2 plants/m^2). In Santo Tomas, where ***C. rotundus*** density in rice is about 2 plants/m^2***, C. rotundus*** in onion also increased to 9-14 plants/m^2. In Palestina, where the highest ***C. rotundus*** densities in rice were observed (4-8 plants/m^2), its densities in onion were also highest at 19-20 plants/m^2.

The ***C. rotundus*** densities in our survey are relatively low because the farmers observed standard weed control practices and also because of the presence of other weeds in both rice and onion fields. Romanowski and Nakagawa (1967) also observed a comparable density of 14 plants/m^2 of ***C. rotundus*** mixed with other weeds in vegetable fields in Hawaii. Much higher densities have been reported in pure controlled stands of ***C. rotundus,*** ranging from 100 to 1000 plants/m^2 in upland rice in the Philippines (Okafor and De Datta, 1974; 1976); 317 plants/m^2 in vegetables in Hawaii (Romanowski and Nakagawa, 1967); and 400 to 1000 plants/m^2 in vegetables in Brazil (William and Warren, 1975). Full season competition from ***C. rotundus*** at these densities have reduced yields by an average of 42% in upland rice (Okafor and De Datta, 1974), 35% to 60% in beans, carrot, cabbage, cucumber, okra and tomato (William and Warren, 1975), and 88 to 89% in garlic and onion (William and Warren, 1975; Paller et al, 1973). In pot-grown cotton plants, ***C. rotundus*** densities as low as 5 to 20 plants/m^2 reduced the crop shoot biomass by about 50% (Guantes, 1974).

Onion is a poor competitor against ***C. rotundus*** because of its short stature and narrow, erect leaves which cannot provide a canopy to shade out weeds. Shading, an indirect alternative weed management approach, is an effective strategy against ***C. rotundus*** because it is a C-4 plant requiring high levels of irradiation (Stoller and Sweet, 1987; Ampong-Nyarko and De Datta, 1989). Shading levels as low as 20% to 50% of full sunlight can reduce ***C. rotundus*** tuber and shoot biomass by 30 to 50% (Santos et al, 1997b; Bantilan et al, 1974). In crops with well-developed canopies like tomatoes, shading is an effective management strategy against ***C. rotundus*** (Santos et al., 1997a). Unfortunately, the shading strategy will not work in onions. This explains why yield losses in onion due to competition from ***C. rotundus*** are two-fold higher (89%) than those in vegetables with well-developed canopies (35% to 60%) (Paller et al, 1973). Upland rice, which is taller than onion, but also with narrow, erect leaves which can not shade out ***C. rotundus*** had its yield reduced by 42% from full-season competition with this weed (Okafor and De Datta, 1974). With the lowland type of ***C. rotundus*** which we observed growing in lowland rice in this survey, shading is even less effective because this type reached a height of 100 cm, thus, is as tall as rice (Baltazar et al, 1997).

In terms of weed management, higher populations of ***C. rotundus*** in onion implies greater problems because no selective control measures other than handweeding are available against ***C. rotundus*** when it grows with vegetables. All the currently available selective herbicides for vegetables are not effective against this weed. Those that can control it are not selective to vegetables. For this reason, its presence in rice may provide an alternative management strategy because it opens up the possibility of applying control measures in the rice crop which are not possible during the onion crop due to selectivity problems. The current herbicides used in rice for sedge control (bensulfuron, 2,4-D, MCPA, bentazon) are also effective against ***C. rotundus.*** Applying direct control measures against this weed in the rice crop, coupled with indirect control measures in the onion crop, may result in decreased infestations not only in rice but in the onion crop as well. One effective indirect control practice is soil tillage and cultivation during the fallow period before onion is planted to expose ***C. rotundus*** tubers to the soil surface because the tubers desiccate and lose viability at moisture levels below 11 to 15% (Mercado, 1979; Stoller and Sweet, 1987). This multi-season, multi-crop approach to weed management has been suggested since the 1970s (Harwood and Bantilan, 1974; Shetty, 1986).

When studies on weed control in multiple cropping systems were initiated 20 years ago, researchers have debated on the issue of whether multiple cropping systems reduce or increase weed infestations (Moody, 1977a; Mercado, 1977). Plucknett et al (1977) argued that each cropping system has its own weed problems and that the important questions should focus on the nature and effect of the weed species present in a particular cropping system. Our survey of weeds in rainfed rice-onion systems show that, in addition to the major weeds infesting each crop, certain weed species are growing in both crops due to factors related to water management. The appearance of weeds in both crops implies greater infestation and is an area of concern of this project. However, it also provides an opportunity to apply weed management practices based on a rotation systems approach, a strategy which has been suggested since the initiation of multiple cropping studies in 1970s. To this date, most existing weed management practices in the Philippines are still largely based on a single-crop, single-season approach, in spite of the fact that about one-half of the cropped areas are rainfed areas with rice-based multi-crop rotation systems. Consequently, the weed control methods used are largely direct (therapeutic) methods used in isolation and independent of methods applied to other crops in the rotation system. The ultimate aim of this project is to develop alternative (prophylactic) strategies based on a rotation systems approach to managing weeds in rice-onion systems. Hopefully, this will reduce use of time, money, and labor-consuming direct control inputs, and consequently reduce production costs.

Legend, Figures 2-4. Rice weeds: **Grasses:** Esp = ***Echinochloa crusgalli*** and ***E. glabrescens***; Ir = ***Ischaemum rugosum;*** Ec = ***Echinochloa colona;*** Ds = ***Digitaria setigera;*** Os = ***Oryza sativa*** (red rice); Ei = ***Eleusine indica;*** Pd = ***Paspalum distichum;*** Dc = ***Digitaria ciliaris;*** Cda = ***Cynodon dactylon;*** Lh = ***Leersia hexandra;*** **Sedges**: Cr =***Cyperus rotundus;*** Ci = ***Cyperus iria;*** Cdf = ***Cyperus difformis;*** Fm = ***Fimbristylis miliacea;*** Cc = ***Cyperus compressus***; Ss = ***Scirpus supinos;*** **Broadleaf weeds**: Lsp = ***Ludwigia octovalvis and L. perennis;*** Sz = ***Sphenoclea zeylanica;*** Mv = ***Monochoria vaginalis;*** Tp = ***Trianthema portulacastrum;*** Ep = ***Eclipta prostrata;*** Hb = ***Hedyotis biflora***; Ml = ***Macroptilium lathyroides;*** Ia = ***Ipomoea aquatica;*** **Onion weeds**: **Grasses**: Ec = ***Echinochloa colona;*** Dc = ***Digitaria ciliaris;*** Ei = ***Eleusine indica;*** Pd = ***Paspalum distichum;*** Os = ***Oryza sativa*** (volunteer rice); Cda = ***Cynodon dactylon;*** **Sedges:** Cr = ***Cyperus rotundus;*** Fm = ***Fimbristylis miliacea***; Ci = ***Cyperus iria;*** **Broadleaf weeds**: Cv = ***Cleome viscosa;*** Tp = ***Trianthema portulacastrum;*** Pa = ***Phyllanthus amarus;*** Ml = ***Macroptilium lathyroides;*** It = ***Ipomoea triloba;*** Ct = ***Cassia tora;*** Hi = ***Heliotropium indicum;*** Csp = ***Crotolaria sp.;*** Sj = ***Stachytarpeta jamaicensis;*** Mp = ***Mimosa pudica;*** Gp = ***Galinsoga parviflora;*** Pm = ***Panicum maximum;*** Eh = ***Euphorbia hirta;*** Ep = ***Eclipta prostrata;*** Po = Portulaca oleracea; Cdi = Commelina diffusa.

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